EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology 2023, 24(4), 73–78
https://doi.org/10.12912/27197050/161962
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Received: 2023.02.11
Accepted: 2023.03.27
Published: 2023.04.10

Surface Temperature Prediction Using Long Short-Term Memory – Case Study Java Island, Indonesia

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ABSTRACT

We predict the surface temperature of Java Island in Indonesia based on a dataset of wind speed, surface temperature, and surface pressure from 2002 to 2021. Long short-term memory model is employed to predict the surface temperature in 2022. The predicted surface temperature corresponds to the seasons of Indonesia. The result shows a pattern between dry and monsoon seasons of Indonesia. The performance of the model is evaluated using root mean square error. The root mean square error in the land area is larger than the water area.

Keywords: long short-term memory, wind speed, surface temperature, surface pressure, Hovmöller diagram.

INTRODUCTION

The atmospheric condition of Java Island mainly influenced by the dynamic of Java Sea and Indian Ocean. The study of atmospheric conditions in Java Island is an important aspect to accelerate the productivity of the socio-economic aspects of Indonesia. Java Island is one of the largest Island in Indonesia archipelago, and it is most populated Island. The geomorphology of Java Island is diverse, from high to low altitude. The north of Java Island is dominated by low altitude land. The south region is dominated by mountains [Saputra et al., 2003; Livneh et al., 2017].

Indonesia has two major seasons which are dry and monsoon seasons [Koesuma et al.; 2021, Lestari et al., 2019]. Dry season in Indonesia is characterized by low precipitation and temperature levels. On the contrary, the monsoon season is characterized by high precipitation and temperature levels. The dry season occurs between April and September, and the monsoon season occurs between October to March [Chang et al., 2005; Hendon, 2003]. The season shifting from dry to monsoon and vice versa in Indonesia is influenced by the rainfall changes and the temperature level [Irsyad and Oue, 2021; Avia, 2019].

Long short-term memory or in short LSTM is recurrent neural network algorithm which employs feedback connection. The study of LSTM involves not only theoretical but also practical used. LSTM is widely used for prediction of sequence data especially in speech recognition, image processing, autonomous system, financial market and manufacturing industries [Fischer and Krauss, 2018; Shewalkar et al., 2019; Cao et al., 2019]. Moreover, the LSTM algorithm is suitable to predict time dependent data, for instance weather data [van Houdt et al., 2020; Hua et al., 2019; Zhang et al., 2017].

In this paper, we apply the LSTM model to predict the surface temperature of Java Island and its surrounding in Indonesia. The prediction result is based on the training data that contains surface temperature, surface pressure, and wind speed. The model performance is measured based on its root mean square error.

METHOD AND MATERIALS

The data are collected from the European Center for Medium-range Weather Forecasts (ECMWF). The data consist of daily reanalysis data

of wind u and v vector components, 2 meters surface temperature, and surface pressure from 2002 to 2022. The dataset is located at 104°E – 117°E and 4°S – 11°S with resolution 0.25°. Figure 1 illustrates the dataset location located in Java Island, one of biggest Islands in Indonesia, and its surroundings including Java Sea at the north and Indian Ocean at the south.

Data preparation consists of several steps. The first step fills the empty or zero value in the dataset with its mean. This step is applied to each variable which is wind, temperature, and pressure. The second step is to convert the unit of temperature data and the value of pressure data. The temperature data units are converted from Kelvin to Celsius. Meanwhile, the pressure data values are subtracted by 10^5. The fourth step is to resample the dataset to monthly mean data. For wind data, we calculate the wind speed using equation as follow:

$$W = \sqrt{u^2 + v^2} \tag{1}$$

where: W – the scalar field of wind speed;
u and v – the vector component of wind speed with respect to x and y coordinates, respectively.

The fifth step is to compute the data monthly climatology for wind speed calculated from Equation 1, temperature, and pressure. The final step is to plot the monthly climatology data into a Hovmöller diagram.

Data preprocessing, processing, and postprocessing use python libraries including NumPy, xarray, pandas, Matplotlib, Cartopy, and Keras. NumPy, pandas, and xarray are used for array manipulation and operation [Harris et al., 2020; Hoyer and Hamman, 2017; McKinney, 2010]. The plotting of graphs and figures is handled by Matplotlib and Cartopy [Hunter, 2007; Met Office, 2017]. The LSTM model used in this paper is from Keras module [Chollet, 2018].

The predicted surface temperature is calculated using the LSTM model. The dataset is divided into training and testing data. For the training data, the surface temperature data from 2002 and 2021 are used. The testing data use the 2022 surface temperature data. The performance of the LSTM model is measured using root mean square error (RMSE) between predicted surface temperature and testing data. RMSE is calculated as follow:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(s_i - \hat{s}_i)^2}{N}} \tag{2}$$

where: N – the number of data points;
s_i – the actual or observation data;
$\hat{s}_i$ – the predicted data.

RESULT AND DISCUSSION

The results of the plotting dataset into the Hovmöller diagram are shown in Figure 2. The Hovmöller diagrams are plotted with respect to the average of the latitude. Figure 2a illustrates the result of surface temperature monthly

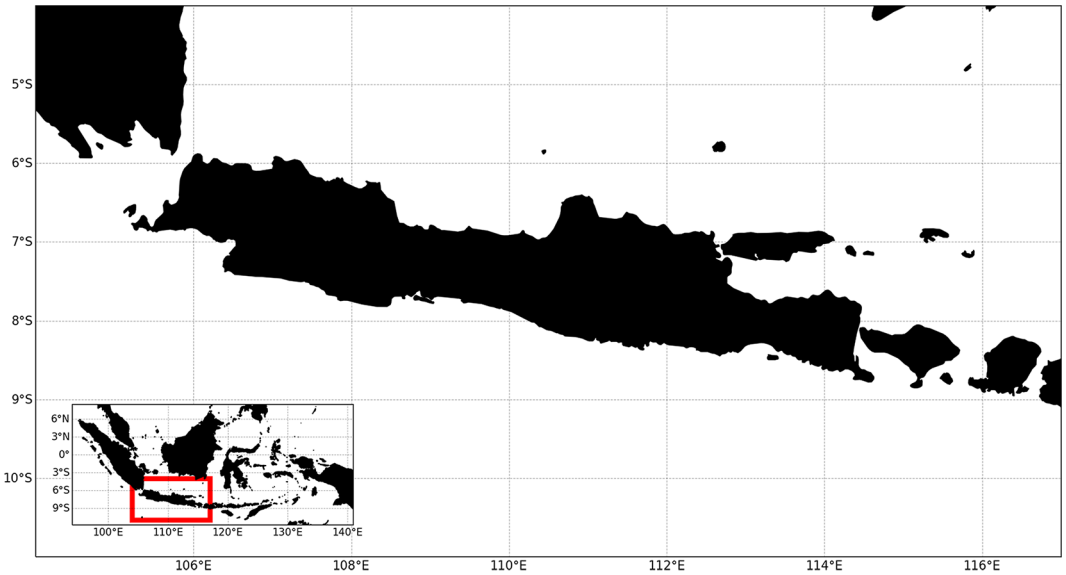

Figure 1. Dataset location as a study case in Java Island, Indonesia. The black block shape is land and otherwise is water

climatology. The surface pressure of Java Island and its around ranged from about 25 °C to 28 °C. The highest surface temperature occurs from February to May at 114°E to 117°E. Contrary, the lowest surface temperature occurs from July to October at 104°E to 108°E. The lowest point comes about 108 °C in August. The highest point arises about 116 °C in April. We assume that the blue region in Figure 2a is the cold surface temperature and the red region is the hot surface temperature. Overall, the cold surface temperature happens starting from July to October and the hot surface temperature happens starting from December to May. The surface temperature of the other months including June and November is in transition between cold and hot temperature.

The Hovmöller diagram of surface pressure is depicted in Figure 2b. The figure shows a distinct pattern between low, transition, and high surface pressure monthly climatology. The lowest surface pressure is about 850 Pa and the highest surface pressure is about 1180 Pa. The low surface pressure happens in December to February across the longitude. On the other hand, the high surface pressure occurs in July to October across the longitude. There are two regions of transition surface pressure which are about May and November.

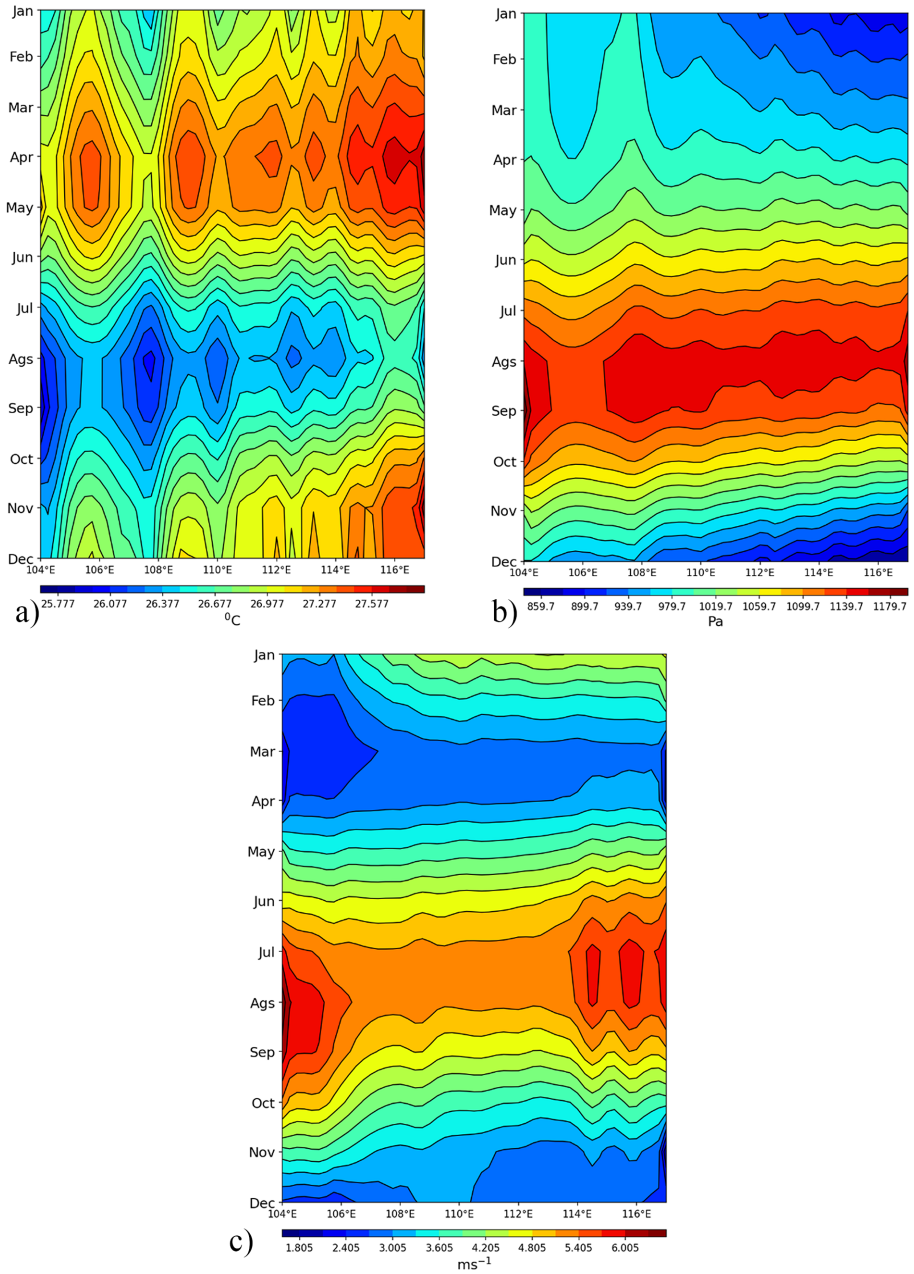

Figure 2. Hovmöller diagram of (a) surface temperature, (b) surface pressure, and (c) wind speed

Figure 2c shows the Hovmöller diagram of wind speed. The lowest wind speed is around 1.8 m/s and the highest wind speed is around 6 m/s. Overall, high wind speeds indicated by the red region happen between June and October. The transition, moderate wind speed, occurs in May and November. Moreover, the low wind speeds indicated by the blue region happen between December to April. The pattern of the Hovmöller diagram of wind speed is similar to the pattern of the Hovmöller diagram of surface pressure. To be specific, the higher the surface pressure, the faster the wind speeds blow.

The Hovmöller diagram in Figure 2 shows a corresponding pattern between surface temperature, surface pressure, and wind speed. Overall, the higher the wind speed, the lower the surface temperature is. The faster wind speed will decrease the surface temperature. The lowest the surface temperature will increase the surface pressure.

From the data, we see that the dry season of Java Island and its around occurs from October to May. This season is indicated by high surface temperature and low surface pressure. On the other side, the monsoon season rises from June to September. The lowest surface temperature and highest surface pressure is between these months. The wind data also shows correlation with the surface temperature and pressure data. Fast wind speed influences the surface temperature to decrease and slow wind speed exhibit inversely, negative correlation. Between wind speed and surface pressure, a positive correlation is happened.

The predicted surface temperature in 2022 is shown in the Hovmöller diagram (Figure 3). The high temperature occurs from January to the beginning of April. The low temperature occurs from the middle of June to the middle of August. There are two transitions of surface temperature from high to low temperature and vice versa in Figure 3. The first transition happens around May and the second happens from September to December. The lowest point of surface temperature is about 26 °C and the highest is about 28 °C.

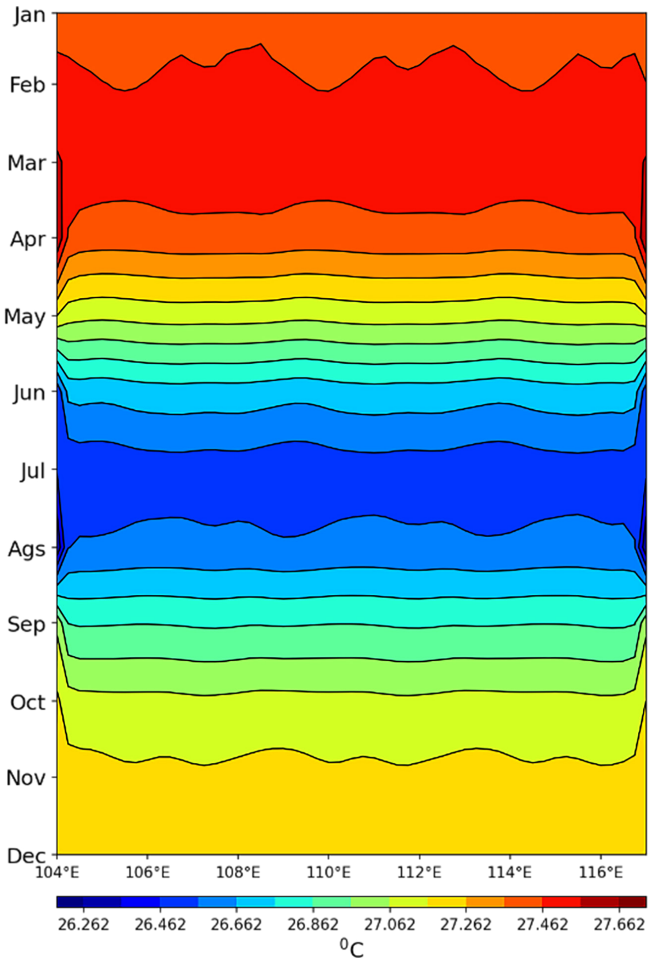

Figure 3. Hovmöller diagram of predicted surface temperature

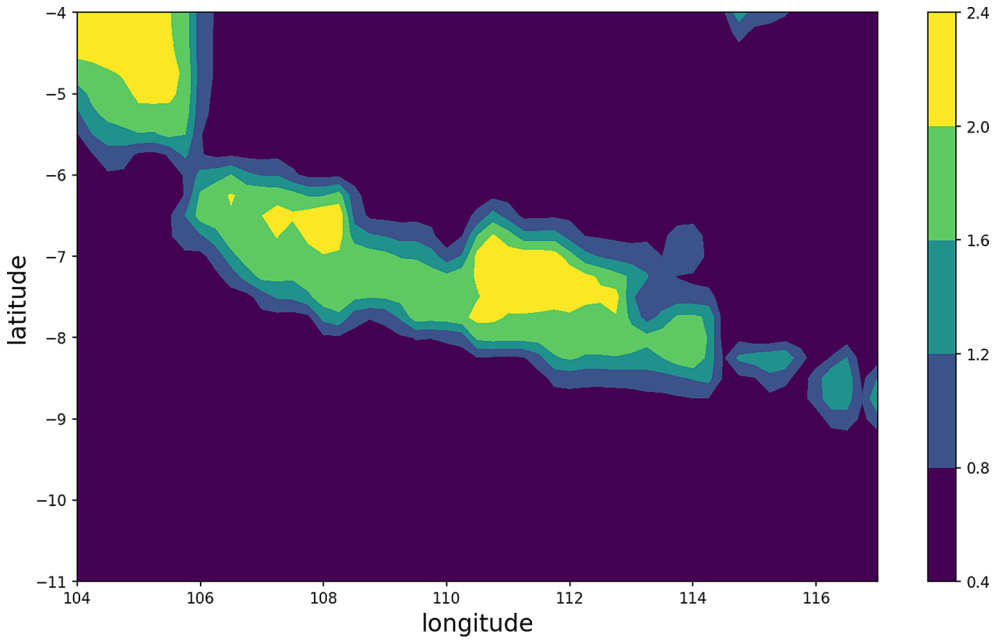

Figure 4. RMSE of predicted surface temperature with respect to the dataset

The predicted surface temperature depicts the mean temperature across latitude. What we can see from Figure 3 is the pattern of surface temperature in a year across Java Island and its around. The dry season in 2022 occurs from October to April and the monsoon season occurs from May to September. The dry and monsoon seasons based on the predicted surface temperature correspond to wind speed and surface pressure data illustrated in Figure 2b and 2c.

The model performance calculated using Equation 2 is illustrated in Figure 4. The RMSE of each coordinate in the dataset shows that the maximum RMSE is 2.4 °C and the minimum is 0.4 °C. From the RMSE plot in Figure 4, patterns appear that the land has higher RMSE than the waters.

The RMSE values inform the deviation between predicted surface temperature value and surface temperature data at the same point. The deviation becomes larger in the land area than in the waters. This means that surface pressure is influenced by the land topography. The smoother or the more invariant the topography is, the smaller the deviation of predicted surface pressure.

CONCLUSION

We have applied the LSTM model to predict the surface temperature of Java Island in Indonesia. The predicted surface temperature based on Hovmöller diagram shows patterns that correspond to wind speed and pressure data. The highest RMSE is 2.4 °C and the lowest RMSE is 0.4 °C. The highest RMSE occurs in the land area because of the land topography more diverse than the waters.

Acknowledgments

We thank to Department of Oceanography, Diponegoro University for providing the computing resources.

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